Technical Evaluation of TD-LTE for Low-band Spectrum

19 September 2013

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Introduction

- Deploying TD-LTE at 600 MHz will result in efficiency losses and operational deficiencies
  - Some of the notable drawbacks of TD-LTE in low-frequency spectrum include link budget deficits compared to FDD LTE, performance constraints compared to FDD LTE, and real-world limitations on the feasibility of variable downlink-uplink configurations

- Compensating for the difference in coverage between FDD LTE and TD-LTE is very difficult
  - TD-LTE is an option in capacity limited environments, greatest benefit of 600MHz is its coverage characteristics

- 600MHz as Supplemental Downlink provides improved end user experience, but does not provide a coverage gain
  - TD-LTE is an alternative for SDL, but guard band requirements need to be considered

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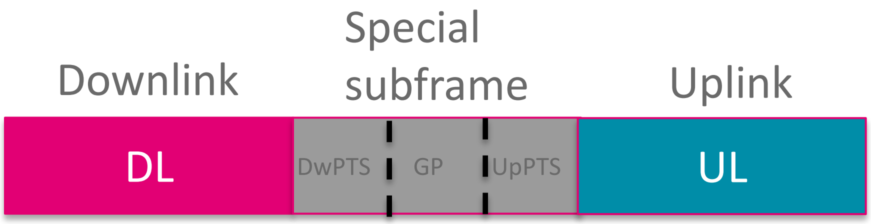
TD-LTE in a nutshell

- Special Sub-frame separates Downlink transmissions from Uplink transmissions
  - This is needed to synchronize arrival of Uplink transmissions at BTS



- TD-LTE has 7 UL/DL configurations
  - Same UL/DL configuration in all cells across the network, as well as in networks on adjacent frequency blocks

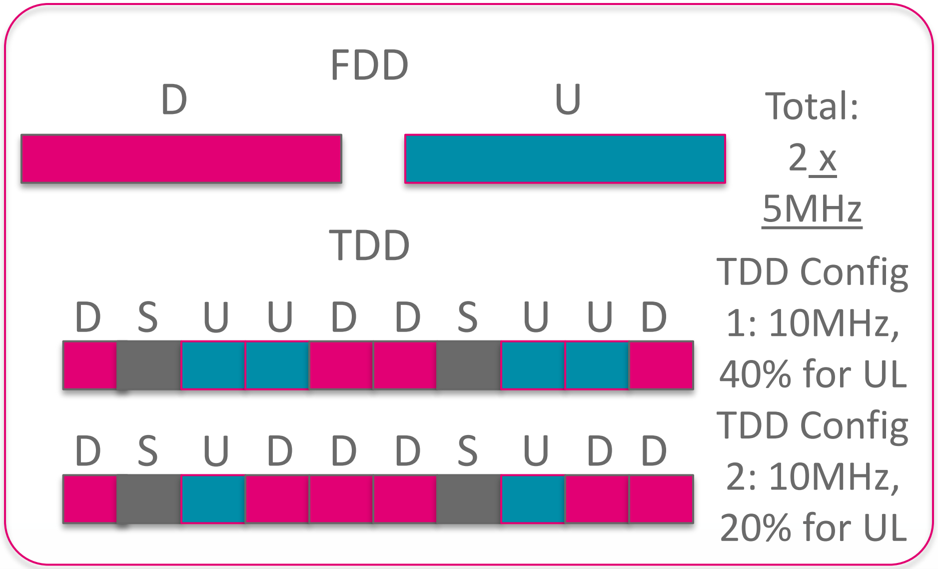
UL/DL configuration	Switch-point periodicity	DL/UL Ratio	Subframe number									
			0	1	2	3	4	5	6	7	8	9
0	5 ms	1:2	D	S	U	U	U	D	S	U	U	U
1	5 ms	2:2	D	S	U	U	D	D	S	U	U	D
2	5 ms	3:1	D	S	U	D	D	D	S	U	D	D
3	10 ms	6:3	D	S	U	U	U	D	D	D	D	D
4	10 ms	7:2	D	S	U	U	D	D	D	D	D	D
5	10 ms	8:1	D	S	U	D	D	D	D	D	D	D
6	5 ms	3:5	D	S	U	U	U	D	S	U	U	D

- The Special Subframe that separates Downlink and Uplink includes the Guard Period (GP) as well as Downlink and Uplink Pilot Timeslots
  - In addition to control information. Downlink Pilot Time Slot (DwPTS) can carry data - The smaller the GP, the higher the DL capacity

Format	Normal CP (DL and UL)			Extended CP (DL and UL)		
	DwPTS	GP	UpPTS	DwPTS	GP	UpPTS
0	3	10	1	3	8	1
1	9	4		8	3	
2	10	3		9	2	
3	11	2		10	1	
4	12	1		3	7	2
5	3	9	2	8	2	
6	9	3		9	1	
7	10	2		-	-	-
8	11	1		-	-	-

TD-LTE Link Budget Summary

- Every Downlink connection needs an Uplink connection for e.g. Channel feedback and Acknowledgements
- To make a fair comparison one should assume same transmission period and same data volume to be transferred in both systems (FDD and TD-LTE)
  - same data rate for cell-edge criterion (link budget), network loading and total spectrum



- For equivalent data rates in both FDD LTE and TD-LTE, TD-LTE needs to transmit more user bits per Transmit Time Interval (TTI). This is because time as a resource is split between DL and UL, resulting in less TTIs available for UL transmission compared to FDD.
  - Resulting in increased coding rate in TD-LTE and less coverage at cell-edge
  - Effect is even stronger for DL dominant asymmetric frame configuration
  - TD-LTE coverage is about 5dB (symmetrical UL/DL) to 8dB (3:1 DL/UL asymmetry) worse than FDD LTE

From an UL coverage perspective, FDD-based systems have an advantage over TDD

Cell Edge Considerations

- Uplink is used not only for data transmissions, but also for session establishments and control signaling
  - LTE has two types of physical channels, transport and control channels
    - Transport channels include Physical Downlink/Uplink Shared Channel (PDSCH, PUSCH), which are the main data bearing channel
    - Control Channels include Physical Random Access Channel (PRACH) for connection establishment and Physical Uplink Control Channel (PUCCH) for control messages such as acknowledgements
  - Uplink dimensioning needs to be sufficient for both Transport Channel as well as Control Channel needs
    - The higher the Uplink cell edge speed, the more control signaling capacity there is
  - Uplink Noise Rise (NR) measures the increase of power at the NodeB due to simultaneous mobile transmissions in adjacent cells
    - This is a function of load, as cells get more loaded UL Noise Rise increases

- It may be possible to compensate for the link budget difference by reducing the load per MHz or by having a lower cell edge Uplink target
  - Neither mechanism will provide significant improvement in coverage

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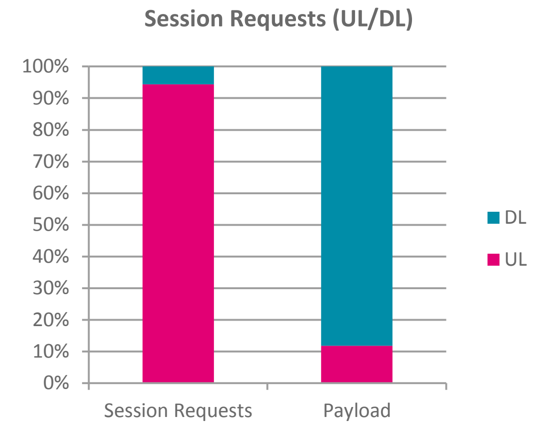
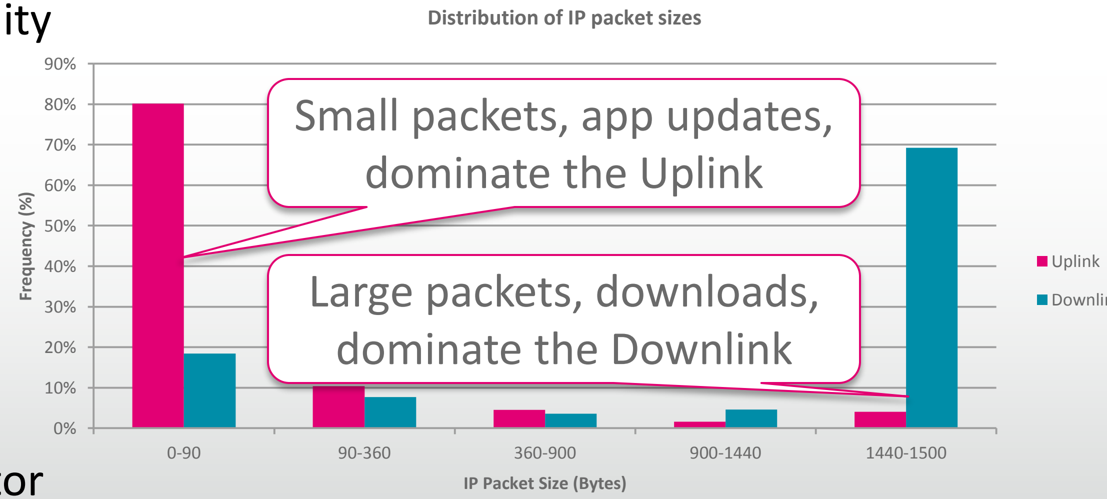
Lower Cell Edge UL target

- LTE is Uplink limited
    - But unlike in Downlink that is all about throughput, control signals and session requests drive the performance
- Cell Edge UL needs to be sufficient for control channel needs, reducing Cell Edge target will negatively impact signaling ability
- More than 90% of Session Requests happen in Uplink
    - Driven by smartphone applications
- 10-15% of payload happens in Uplink
    - But signaling capacity is becoming the limiting factor





Cell Edge Uplink target can not be reduced significantly to improve coverage without impacting signaling capacity resulting in throughput and access degradation

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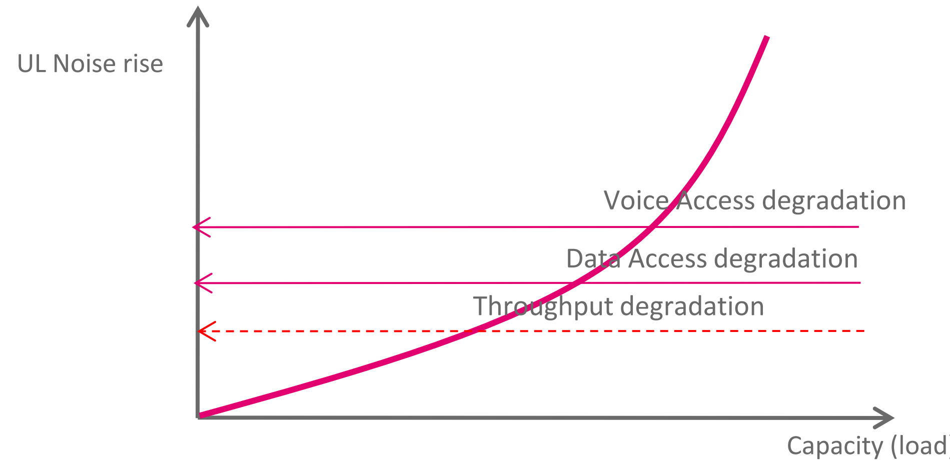
Reducing load per MHz

- Reducing the load per MHz will improve the coverage
- Based on T-Mobile TD-LTE study, reducing the load from 50% to 25% will only reduce the interference margin by about 1dB
- Even with 25% loading, TD-LTE still has significant coverage deficit compared to FDD LTE
- Loading will increase as a function of time, to keep the loading low additional spectrum is needed

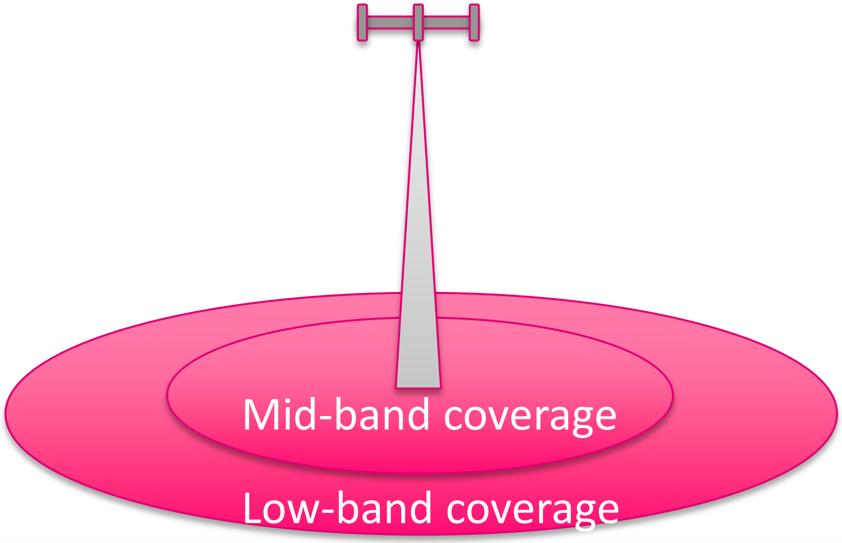
Reduction in load provides about 20% improvement in coverage, which is not enough to bring it close to FDD LTE coverage

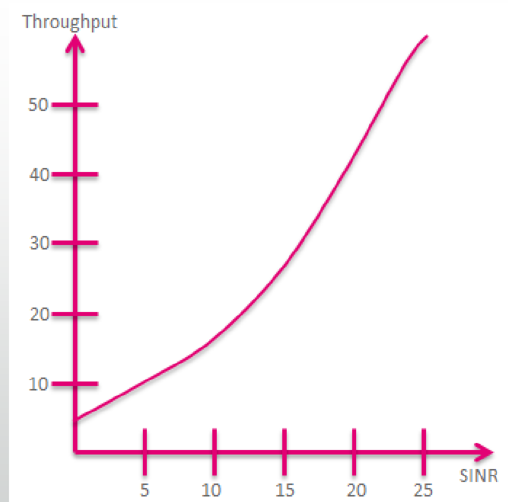


FDD-LTE 600 MHz	TD-LTE 600 MHz (DL:UL= 2:2), 50% load	TD-LTE 600 MHz (DL:UL= 2:2), 25% load
Maximum Allowed Path Loss (131 dB)	-4.8 dB	-3.8 dB
Site Area (6.2 sq km)	-46%	-39%
Sites required (#)	+87%	+64%
Inter-Site Distance (2.66 km)	-27%	-22%

Supplemental Downlink for 600MHz

- Supplemental Downlink coverage is limited to the coverage of the anchor band
  - This is due to Uplink residing in the paired band
- Supplemental Downlink has several benefits though
  1. More urban and suburban capacity
  2. Better service in terms of higher data speeds and ability to support more users.
  3. Perceived improved indoor coverage due to higher Downlink speeds
- TD-LTE is an alternative for Supplemental Downlink
  - However guard band considerations and FDD LTE and TD-LTE co-existence requirements for network and devices needs to be taken into consideration





Drive testing
2x2 MIMO
10 MHz FDD Carrier

Summary

- For national mobile broadband deployments FDD LTE has important advantages over TD-LTE especially at low-frequency bands:
  - Lower site count – reduces carrier costs and takes full advantage of low-band propagation characteristics
  - Improved in-door experience in urban areas – allows carriers to service in coverage limited scenarios even in urban areas
  - Higher maximum data rates – allows consumers to enjoy a better end-user experience for both uplink and downlink use cases

- Compensating for TD-LTE coverage deficit compared to FDD LTE is very difficult and results in tradeoffs in performance

- Supplemental Downlink spectrum has benefits in improving Downlink performance
  - TD-LTE is an option for Supplemental Downlink, but guard band requirements and FDD/TDD co-existence needs to be considered

Thank you

Special Sub-frame and impact to DL capacity

- Let's look at DL capacity per frame
  - Typical UL/DL Configurations, configurations 1 and 2
  - For large cells Special Sub-frame format 5, 3 DwPTS symbols
  - For urban scenario's Special Sub-frame format 7, 10 DwPTS symbols
  - Typically 3 DwPTS symbols used for control signals, rest can be used for DL data
- 10MHz of TDD spectrum, 5+5MHz of FDD spectrum

- **Asymmetric configurations give more DL capacity, at the expense of UL**
- **Symmetrical configurations are less efficient than FDD in coverage driven large cells**

UL/DL configuration	Switch-point periodicity	DL/UL Ratio	Subframe number									
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1	5 ms	2:2	D	S	U	U	D	D	S	U	U	D
2	5 ms	3:1	D	S	U	D	D	D	S	U	D	D
3	10 ms	6:3	D	S	U	U	U	D	D	D	D	D
4	10 ms	7:2	D	S	U	U	D	D	D	D	D	D
5	10 ms	8:1	D	S	U	D	D	D	D	D	D	D
6	5 ms	3:5	D	S	U	U	U	D	S	U	U	D

UL/DL Config	S Format	# of DL symbols	# of UL symbols	Efficiency vs FDD
1	7	70	56	100% (DL), 80% (UL)
1	5	56	56	80% (DL,UL)
2	7	98	28	140% (DL), 40% UL
2	5	84	28	120% (DL), 40% (UL)